

NOTE: The Albuquerque Operations Office (ALO) developed this study material in support of the Technical Qualification Program's Problem Analysis/Risk Assessment functional standard. It is added to this study guide for your convenience. This portion of ALO's study material relates to Occupational Safety competency 1.4. This file is an exact copy of the materials designed by ALO.

Accident Analysis and Investigation

**Section
6**

OBJECTIVE

Demonstrate knowledge of accident causation theories as well as accident investigation, analysis, and reporting as practiced within the DOE.

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- 1. Discuss accident causation models, emphasizing the importance of human reliability and effective management systems.**

The job of DOE management and technical personnel is to identify the hazards that exist within the DOE facilities and eliminate or mitigate those hazards before accidents occur. In performing this work, it is important that these personnel have a fundamental understanding of the accident causation theories and its interpretation of the human factors and workplace variables which can result in accidents. This knowledge and awareness of these concepts will assist those DOE personnel in recognizing and communicating the safety problems to the facility management and technicians.

Single Factor Theory

This theory is very limited in that it assumes that every accident has only a single and simple cause. An application of this theory can be demonstrated by reviewing what causes a forklift operator puncturing a radioactive storage drum. According to this theory, the cause of the accident is the forklift. Yet, by identifying this cause would not mitigate or stop the problem. This theory fails to look at other contributing factors such as worker training, storage method, or corrective actions. This myopic focus makes this theory useless for accident and loss prevention.

Domino Theories

There are three different domino theories of accident causation: Heinrich's, Bird and Loftus', and Marcum's Domino Theories. Each domino theory presents a different explanation for the cause of accidents, however, each theory is predicated on the fact that there are three phases to any accident. The three phases are the pre-contact phase, the contact phase and the post contact phase.

The pre-contact phase are the events or conditions that lead up to the accident.

The contact phase is the phase when the accident actually occurs.

The post-contact phase refers to the results of the accident.

Domino theories represent accidents as causal factors or hazard events. Each causal factor affects the others if allowed to build up over time (pre-contact phase). Without intervention, the hazards will interact to cause the accident and move into the contact phase. Thus the derivation of the theory's name as Domino.

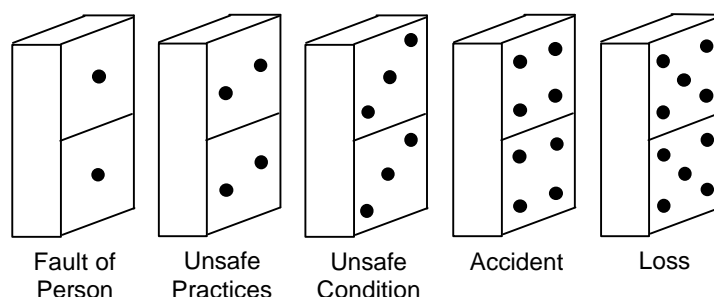
Heinrich's Domino Theory

Heinrich's domino theory essentially states that there are five series factors that could influence an accident. The factors occur sequentially and consist of the following:

1. A negative trait or factor is present in a person as a result of social influence of environment
2. The negative trait or factor may lead to an unsafe practice or condition
3. The unsafe practice results in an unsafe condition, or it results in mechanical or physical hazards that are the direct cause of an accident
4. Accidents that result from the above process are typically the result of falls or impacts with other moving objects
5. Injuries from above are usually of the form of lacerations and fractures.

As a result of this process, intervention or elimination of any of the first four factors will stop the injury or loss.

Heinrich's Domino Theory



Bird and Loftus' Domino Theory

Figure 6.1

Similar to the Heinrich’s Theory, this theory states that there are five series factors that could influence an accident. However, this theory states that the ultimate responsibility for the welfare of the employees lie with the management of an organization. It is the manager of the organization who can instill the controls necessary to prevent the initiation of the domino effect.

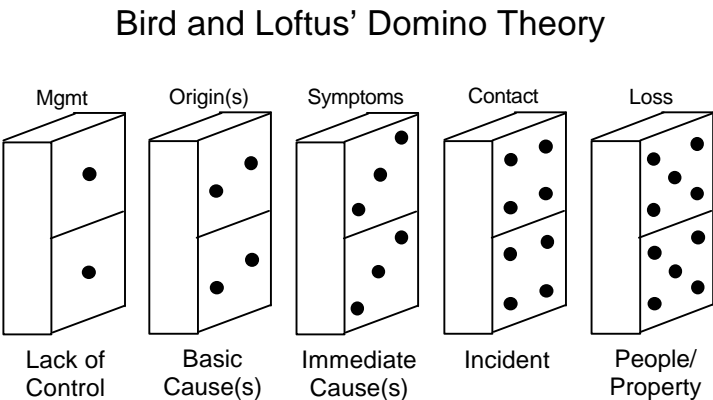


Figure 6.2

1. Lack of Control - Management
Control in this instance refers to the four functions of a manager: planning, organizing, leading and controlling. Examples of this domino are purchasing substandard equipment or tools, not providing adequate training, or failing to install adequate engineering controls.
2. Basic Cause(s) - Origin(s)
The basic causes are frequently classified into a personal factors group and a job factors group. Personal factors may be lack of knowledge or skill, improper motivation, and physical or mental problems; job factors include inadequate work standards, inadequate design or maintenance, normal tool or equipment wear and tear, and abnormal tool usage.
3. Immediate Cause(s) - Symptoms.
The primary symptoms of all incidents are unsafe acts and unsafe conditions.
4. Incident - Contact
An undesired event occurs. The accidents are often represented by the eleven accident types in Table 6.1.

Eleven Accident Types

stuck-by	caught-in	fall-to-below
struck-against	caught-on	overexertion

Table 6.1

contact-by	caught-between	exposure
contact-with	foot-level-fall	

source: ANSI Z 16.2

5. People – Property – Loss

Result of the accident. The effects are property or environment damage or injury to personnel.

Marcum's Domino Theory

According to C. E. Marcum's 1978 Seven Domino Sequence of Misactsidents, a misactsident is an identifiable sequence of misacts associated with *inadequate task preparation* which could lead to *substandard performance* and *miscompensated risks*. Marcum also includes the cost aspect of a loss. Like the previous theory, Marcum states that management is ultimately responsible to ensure that the workplace is designed with adequate controls to protect employee.

Marcum's Domino Theory

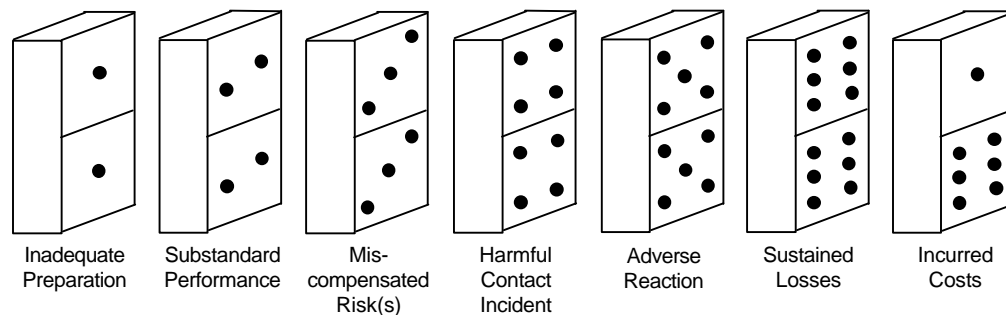


Figure 6.3

Through this domino theory, Marcum shows that accidents can be prevented by the management by properly training the employees as well as designing adequate controls into the work process.

Multiple Causation Accident Theories

Multiple Factors Theory

The multiple factors theories use four M factors, as shown in Table 6.2, to represent causes of accidents. Multiple factors theories attempt to identify the hazardous condition (pre-contact) that exist in an operation by revealing the causes that will lead to an accident.

Table 6.2

Grose's Accident Factors

Factor	Description	Characteristics
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Machine	tools, equipment, or vehicles that may contribute to an accident	design, shape, size, specific type of energy used to operate equipment
Media	environmental conditions surrounding an accident: weather, walking surface	gender, age, height, weight, condition, memory, recall, knowledge level
Man	people and human factors that could contribute to an accident	snow or water on a roadway, temperature of a building, outdoor temperature
Management	method used to select equipment, train personnel, or ensure a relatively hazard-free environment	safety rules, organization structure, policy and procedures

Systems Theory of Causation

This theory states that the probability of an accident lies with how the worker, machine, and environment interact with each other. For example the knowledge, skills, and ability, whether acquired through training or gained from years of experience, influences the way a person deciphers the information regarding the environment as well as how he will use the machinery. This, in effect, will affect his decision making and therefore will have a bearing on the person performing a job and therefore influence the probability of a mishap.

Psychological/Behavioral Accident Causation Theories

Goals Freedom Alertness Theory

According to this theory, accidents are the result of low-quality worker behavior. Correction to this behavior is in the form of raising worker awareness through a positive organizational culture and psychological climate. For example, ensuring that workers are disciplined to maintain good housekeeping will reduce mishaps.

Motivation Reward Satisfaction Model

This theory builds upon the previous theory. According to this theory, rewards are the factor that have the greatest effect upon performance. If rewards are fairly disseminated as perceived by the employees, there is an increased likelihood of motivation which will produce positive safety results. For example, one of the DOE sites decided to implement a program where a pool of safety fund is allotted at the beginning of the year. For every accident, a certain amount of money is reduced from the original allocation. Then at the end of the year, the remaining funds,

if any are divided up among the employees. Since starting this program, the number of mishaps have decreased significantly.

Human Factors Theory

This theory is based on the fact that human errors cause accidents. The three human factors which can lead to human errors are overload, inappropriate activities, and inappropriate response.

Overload can occur when a person must perform excessive number of tasks. Despite whether this person is qualified or not, it is the overburden situation which creates the scenario for a mishap.

An inappropriate activity can occur when a person is not adequately trained to perform his duties. This is one of the reasons for ensuring that any trainee performing a “real” task during an on-the-job training is supervised at all times.

An inappropriate response occurs when a qualified person purposely violates a procedure for productivity or he fails to correct the problem when it is detected.

Energy-Related Accident Causation Theories

Energy Release Theory

According to this theory, an accident is caused by a lack of engineering control. This lack of control results in energy that is out of control which puts causes stress limits to be violated, whether on a person, machinery, or environment. Therefore, accidents can be prevented by instilling a proper engineering control to divert the energy, which is the source of the hazards.

2. Discuss the purpose of accident investigation within the DOE. Discuss the DOE accident investigation methodology.

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Purpose

According to DOE Order 225.1, the purpose of accident investigation is to improve the environment, safety and health for DOE employees, contractors, and the public. A second purpose is to prevent recurrence of accidents.

Accident Investigation

The DOE accident investigation contains four main steps:

1. Categorization
2. Conduct the Investigation
3. Report Investigation Results
4. Investigation Close-Out.

Step 1 Categorization

DOE accidents are categorized as warranting either a Type A or a Type B investigation. The algorithm for determining the type of investigation is found under objective 2.A. The categorization algorithm is also found as Attachment 2 to DOE Order 225.1.

Step 2 Conduct the Investigation

The first step in a DOE accident investigation is the appointment of the Accident Investigation Board. The investigation time frame and board participants are outlined in DOE Order 225.1. The Board's composition is mandated based upon the type of investigation; this information is found in the Order. The second step is the actual accident investigation which is detailed under objective 2.B. The main objective of the investigation is to analyze the facts and identify causal factors and judgments of need for corrective actions.

Step 3 Report Investigation Results

After the Board has prepared the report, it is submitted to the Appointing Official who then accepts the report and its findings. The investigative phase is complete at this point. The investigation report's purpose and content is handled in detail under objective 2.E.

Step 4 Investigation Close-Out

The Appointing Official ensures that the DOE and contractor line management organizations affected by the investigation have had an opportunity to conduct a factual accuracy review of the draft report and present comments to the Board. The Board Chairperson and the senior manager of the site conduct a formal briefing on the outcome of the investigation. The final report is given to senior managers with a request for their organizations to prepare corrective action plans. The lessons-learned from the accident investigation are disseminated DOE-wide. Last, the action plans are completed, and corrective actions are implemented to satisfy the judgments of need identified in the final investigation report.

A. Discuss and demonstrate the ability to apply the criteria for determining the need for a particular type of accident investigation.

DOE Order 225.1 provides an accident investigation categorization algorithm as Attachment 2. This algorithm provides the criteria for categorizing an accident investigation as either a Type A or a Type B investigation. A table representation of the algorithm is found as Table 6.3. It breaks the criteria into four difference categories of effects: Human, Environmental, Property, and Other.

Accident Investigation Categorization Algorithm

Table 6.3

TYPE A INVESTIGATION	TYPE B INVESTIGATION
Human Effects	
Any fatal, or likely to be fatal, injury, chemical or biological exposure to an employee or a member of the public	Any one or series of injuries, chemical exposures, or biological exposures that results in hospitalization of one or more employees or members of the public for more than 5 continuous days
Any one accident that requires the hospitalization for treatment of 3 or more individuals	Any one or series of injuries, chemical exposures, or biological exposures that results in permanent partial disability of one or more employees or members of the public
Any one accident that has a high probability of resulting in the permanent total disability due to injuries, chemical exposures, or biological exposures of DOE, contractor, or subcontractor employees or members of the public	Any one accident or series of accidents within a 1-year time period, resulting in 5 or more lost-workday cases, or any series of similar or related accidents involving 5 or more persons, one or more of which is a lost-workday case.

Problem Analysis and Risk Assessment

<p>A single individual radiation exposure resulting in:</p> <ul style="list-style-type: none"> a. A total effective dose equivalent > 25 rem b. A dose equivalent to the lens of the eye > 75 rem c. A shallow dose equivalent to an extremity or skin > 250 rem d. The sum of the deep dose equivalent for external exposure and the committed dose equivalent to any organ or tissue other than the lens of the eye > 250 rem e. A dose equivalent to the embryo or fetus of a declared pregnant worker > 2.5 rem 	<p>A single radiation exposure to an individual that results in:</p> <ul style="list-style-type: none"> a. A total effective dose equivalent > 10 but < 25 rem b. A dose equivalent to the lens of the eye > 30 but < 75 rem c. A shallow dose equivalent to an extremity or skin > 100 but < 250 rem d. The sum of the deep dose equivalent for external exposure and the committed dose equivalent to any organ or tissue other than the lens of the eye > 100 but < 250 rem e. A dose equivalent to the embryo or fetus of a declared pregnant worker > 1 but < 2.5 rem
Environmental Effects	
<p>Release of a hazardous substance, material, waste, or radionuclide from a DOE facility (onsite or offsite), in an amount greater than 5-times the reportable quantities specified in 40 CFR Part 302, that results in serious environmental damage</p>	<p>Release of a hazardous substance, material, waste, or radionuclide from a DOE facility (onsite or offsite), in an amount \geq 2-times but < 5-times the reportable quantities specified in 40 CFR Part 302, that results in serious environmental damage</p>
Property Effects	
<p>Estimated loss of, or damage to, DOE or other property, including aircraft damage, \geq \$2.5 million or requiring estimated costs \geq \$2.5 million for cleaning, decontaminating, renovating, replacing, or rehabilitating structures, equipment, or property</p>	<p>Estimated loss of, or damage to, DOE or other property \geq \$1 million but < \$2.5 million, including aircraft damage, and costs of cleaning, decontaminating, renovating, replacing, or rehabilitating structures, equipment, or property</p>
<p>Any apparent loss, explosion, or theft involving radioactive or hazardous material under the control of DOE, contractors, or subcontractors in such quantities and under such circumstances to constitute a hazard to human health and safety or private property</p>	<p>The operation of a nuclear facility beyond its authorized limits</p>
<p>Any unplanned nuclear criticality</p>	
Other Effects	

Any accident or series of accidents for which a Type A investigation is deemed appropriate by the Secretary or the Assistant Secretary for Environment, Safety and Health.

Any accident or series of accidents for which a Type B investigation is deemed appropriate by the Secretary; Assistant Secretary for Environment, Safety and Health; Associate Deputy Secretary for Field Management; Cognizant Secretarial Officer; or Head of the Field Element. This includes Departmental cross-cutting issues and issues warranting the attention of local news or interest groups.

B. Discuss and apply the necessary techniques for gathering the facts applicable to a given investigation .

DOE Order 225.1 lists the information that should be gathered by the accident investigation board during an investigation.

The Board shall be responsible for conducting a thorough investigation of all individuals, organizations, and facilities having a stake in the accident.

The Board shall determine the facts of the accident by examining the accident scene, examining DOE and contractor documentation, interviewing witnesses, and performing engineering analyses. The Board shall also examine policies, standards, and requirements that are applicable to the accident being investigated as well as management and safety systems at Headquarters and Field Offices that could have contributed to or prevented the accident.

The purpose of an accident investigation is to determine the causes of the accident. Once the causes are determined, this information will then be fed back to the management, who will then take corrective actions by training the workers or instilling new controls to prevent similar accidents.

All accident investigation should be for the sake of fact finding and not fault finding.

Investigation should be conducted using the who, what, where, when, how, and why questions. For example:

1. Who are the victims?

2. What events lead up to the accident?
3. Where was equipment and/or machinery?
4. When did the incident occur?
5. How did the victims and witnesses react in given situations?
6. Why did the incident take place, in your opinion?

Interviews and document reviews will be the main source of information. However, observations of the place of the accident and the surrounding areas will be invaluable in determining the setting and the environment leading to the accident. All these factors are important to finding the cause as discussed through the use of the various accident theories.

C. Discuss the purpose and content of an accident investigation report.

DOE Order 225.1 outlines the purpose and content of the report. The purpose of the report is to contain the investigation board's judgment on the need for corrective actions based upon objective analysis of the facts, root and contributing causes, and DOE or contractor management systems that could have prevented the accident. The report will not contain statements that determine individual fault or propose punitive measures.

The facts section of the draft investigation report should be offered to the affected DOE and contractor line management for their review of the report's factual accuracy. Prior to completing the investigation, the accident investigation board will review the report to ensure its technical accuracy, completeness and internal consistency. They will also include an analysis of management control and safety systems that may have contributed to the accident.

If a board member wishes to offer an opinion different from that of the investigation board, a minority report section can be added to the report.

D. Discuss the importance of providing feedback based on accident investigations, and describe the management systems necessary to ensure the communication of this feedback to the Department.

Since the DOE operates numerous sites across the country, it is paramount that information learned in the course of an accident investigation be shared throughout the DOE and its contractors. Through the communication and dissemination of accident information which includes lessons learned and corrective actions, all sites benefit. In addition, other sites may analyze their facilities for similar problems and implement needed changes in order to avoid a similar accident or occurrence. When practiced, this process saves lives and money by avoiding repeated accidents.

One of the main tools used to accomplish the communication of accident and occurrence information is the Occurrence Reporting and Processing System (ORPS). This system serves as a historical database for all accident and occurrence report information within the DOE and its contractors. Once the information is stored in ORPS, the DOE Office of Environment, Safety and Health in conjunction with the Office of Nuclear Facility Safety publishes the Operating Experience Weekly Summary. The process is intended to disseminate lessons-learned information as described in DOE-STD-7501-95. In addition to ORPS, the Office of Operating Experience Analysis and Feedback compiles information from daily operations reports, notification reports, and conversations with DOE field office and facility staffs for inclusion in the Weekly Summary. This effort is intended to augment ORPS but should not substitute for a thorough review of interim and final occurrence reports.

References and Suggested Reading

Bird, F. E., and Loftus, R. G., Loss Control Management, Institute Press, Loganville, GA, 1976.

Department of Energy, DOE Order 225.1, DOE, 1996.

Kohn, J. P., Friend, M. A., and Winterberger, C. A., Fundamentals of Occupational Safety and Health, Government Institutes, Inc. Rockville, MD, 1996.

References and Suggested Reading